Merging Carbon Monoxide Life Safety with Energy Conservation Methods

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Residential indoor air quality, historically, has not been a major concern because the envelope and window leakage provided inhabitants with sufficient outdoor air. Older residential buildings are sufficiently leaky such that infiltration alone can meet the minimum outdoor air requirements for residential ventilation. In an increased environmentally conscious society, many individuals have become more aware of their resource consumption, and are implementing enclosure draftstopping, attic insulation, and window replacement.

New homes and older homes retrofitted to produce tighter enclosures have insufficient infiltration to meet ventilation and Indoor Air Quality (IAQ) standards. ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Standard 62.2, "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings", is the only nationally recognized indoor air quality standard developed solely for residences. It recommends pressurization of buildings and maintaining a small positive pressure, relative to the outdoors. ASHRAE 62.2 does not supersede the International Mechanical Code with respect to the volume of outdoor air introduced into a residence.

One would hope that the home indoor environment is free of contaminants, dust, odors and has optimum temperature and humidity control. Good air-quality is a paramount element of a healthy indoor environment. But what if the quality of the air in your home is compromised by an odorless, colorless, poisonous gas? What if this gas was threatening the health of all those who live there?

To understand if our home's IAQ is compromised, one must determine if the required mechanical exhaust ventilation, stack effect, wind, fireplaces, and other naturally vented fossil fuel fired devices create problems for naturally vented combustion appliances, i.e. furnaces and water heaters. Depending on the air tightness of the house enclosure; the answer is most likely yes. All the preceding can cause naturally vented devices to discharge products of combustion into the habitable space. Products of combustion can enter homes through backdrafting (aka – combustion gas spillage) whenever the indoor air pressure is lower than the outdoor air pressure. Backdrafting can occur with fireplaces, furnaces, woodstoves and water heaters when air pressure in the house is lower than outside air pressure.

Most commonly, naturally vented heating appliances (boilers, furnaces, water heaters) will produce by-products of mainly water and carbon dioxide. However, if the combustion from these processes does not have sufficient oxygen, carbon monoxide is formed, which can be an extreme health hazard even at low concentrations.

Carbon monoxide (CO) is a colorless, odorless, poisonous gas. It can be produced when liquid, solid or gas fuel is burned. Carbon monoxide lowers the body's ability to carry oxygen to vital organs such as the heart and the brain. The elderly, young children, infants and people with heart or lung problems are more sensitive to the effects of carbon monoxide. UL-2034 listed CO detectors are not suitable for these individuals because CO levels below 65 ppm (parts per million) are not alarmed within 60 minutes of constant exposure.

Carbon monoxide is a serious issue. The many lawsuits filed regarding CO poisoning and death are a good indicator of the need for better preventative measures in our living spaces. Forensic investigation of many carbon monoxide poisonings or fatalities determines the cause as improper installation, lack of maintenance, and neglect. CO detectors are absent in all instances.

How we protect ourselves from this deadly gas is an exercise in knowing how carbon monoxide is getting into your home.

It's the air pressure! The more we seal our homes for energy conservation the more we change the indoor air quality. The more we seal the more prone our homes are to operate at lower air pressures then previously. When the indoor pressure is lower than that of the outdoors and the depressurization exceeds the natural draft of the chimney this increases the probability that the chimney/flue will work in reverse. This phenomenon of combustion gases being discharged into the habitable space in lieu of being discharged to atmosphere via the chimney is called "backdrafting".

Reducing air infiltration in northern climate homes is the most cost effective means of energy conservation, especially where air infiltration has not been addressed previously. Reducing this infiltration changes the pressurization of the home with respect to the outdoors and can reach significant levels of depressurization as a consequence of furnaces, clothes dryer(s), exhaust fans, water heater, and a fireplace all operating simultaneously. Therefore, verifying that furnaces and water heaters are not backdrafting is a critical step in energy conservation implementation.

Small fans and appliances operating concurrently can exhaust significant amounts of indoor air:

- clothes dryers 150-160 CFM (cubic feet per minute),
- fossil fuel fired, naturally vented furnace (non-condensing type) 100- 120 CFM,
- kitchen hood exhaust 70-100 CFM,
- bathroom exhaust fan 40- 50 CFM, and
- gas-fired domestic water heater 30-40 CFM,

When operating simultaneously, these devices can exhaust between 390 and 470 CFM of indoor air.

Thus, the introduction of outdoor air into a residence is essential to minimize the potential of depressurization. Current codes do not address depressurization. The International Code Council Residential Code (IRC) 2012, section M1301.1 states in part…. "The provisions of this chapter shall govern the installation of mechanical systems not specifically covered in other chapters applicable to mechanical systems." Thus, one must refer to the International Code Council Mechanical Code (IMC) 2012, Table 403.3, for minimum code requirements of outdoor air introduction. Typically, the air change rate results in the greater outdoor air volume requirement. For example, a 1000 ft.^{2} home with equivalent area of habitable basement, 8' ceiling heights, ventilated at 0.35 air changes per hour requires 93 CFM of outdoor air be introduced into the home. Thus, operation of only the clothes dryer can depressurize a home.

Modern kitchens may have large kitchen exhaust fans. Kitchen fans exhausting less than 400 CFM are not required by current codes to provide makeup air at a rate approximately equal to the exhaust air rate.[1, 2] It is improbable that a natural-draft fossil fuel fired device can overcome this level of depressurization, even if draftstopping energy cost avoidance activities have not commenced. Therefore, when the kitchen hood exhaust fan is operating, a furnace, water heater, fireplace and similar devices may allow outdoor air to backdraft through the flues or chimneys of these devices.

An actively burning fireplace, which does not have an independent outside air source and is not equipped with tight-fitting doors that are closed, can draw between 240 and 320 ft.^{3} per minute (CFM) [3] of air from a home. This is sufficient air volume to backdraft other combustion appliances. Fireplaces have an average

efficiency of about 10%. In extreme cases, the chimney draws more heated air then the fire produces. The addition of glass doors to the front of a fireplace has both a positive and negative effect. The glass doors restrict free flow of indoor heated air up the chimney, but at the same time they restrict the radiation of heat from the fire into the room.

The flow of wind against home creates high-pressure on the windward side and low-pressure on the lee side. This low-pressure will allow outdoor air intakes to furnaces, fireplaces and dryer exhaust to pull air out of the house. Chimney terminations on pitched roofs may be exposed to either negative or positive static pressure as well as the variation in velocity and direction. The first attempt at eliminating this backdrafting issue is the installation of chimney termination caps. But, malfunctions may occur with the cap because winds acting on the roof fluctuate, thus no simple method of analysis exists. UL (Underwriters Laboratory) Standards 103, 107, 1777; NFPA (National Fire Protection Association) Standard 21 and ASTM (American Society for Testing and Materials) Standard C315 cover termination cap requirements for various chimney types.

Carbon monoxide may enter your home because an animal has entered the chimney and blocked the flue so that operating fossil fuel fired devices are discharging all the products of combustion into the house. The installation of a screen mesh animal deterrent device at the termination of the flue on the chimney should be the first step in preventing carbon monoxide poisoning.

I recommend solving backdrafting issues by introducing outdoor air to all the devices that require air for combustion; (e.g. furnace, water heater, gas clothes dryer, and fireplaces), such that these devices operate as if they are outdoors.

UL-2034 listed carbon monoxide detectors should be installed in every home. However, UL-2034 listed carbon monoxide detector will not protect you from chronic low level CO poisoning. Only low level CO detectors will minimize your potential exposure to CO poisoning.

Prevention of problems associated with carbon monoxide can be avoided by:

1. Not idling automobiles in enclosed or open garages especially if they're attached to a residence.
2. Never use unvented combustion appliances such as space heaters indoors.
3. Never use barbecues or hibachis' indoors.
4. Never use gas cooktops or ovens to provide space heating.
5. Install detection devices.

Not everyone is going to die from carbon monoxide exposure, but you can protect yourself from carbon monoxide poisoning. Not using this knowledge could be a dangerous thing. Installing a carbon monoxide detection device in the vicinity of the bedrooms, areas in the home adjacent to an attached garage, and in areas adjacent to any fuel-burning appliances is the way to protect your family from odorless, colorless, poisonous and potentially life-threatening gas.

[1] International Mechanical Code (IMC), 2009, Paragraph 505.2
[2] International Residential Code (IRC), 2009, Paragraph M 1503.4
[3] ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) 2008, HVAC Systems and Equipment Handbook, Chapter 34, (based on 6 ft^2 of frontal area and 300°F rise in mean chimney gas temperature)
[4] International Fuel Gas Code, 2009 Appendix D
[5] International Fuel Gas Code, 2009 Section 304

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- March / April 2005, Page 20
- March / April 2007, Page 36
- November / December 2010, Page 38

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- The author may be reached at jim@jpconsulting-llc.com
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- Reports on the lawsuits cited in the article are protected by confidentiality agreements.
- NFPA (National Fire Protection Association) 720, Standard for the Installation of Carbon Monoxide (CO) Detection and Warning Equipment
- www.cpsc.gov.cpscpub/pubs/466.html
- www.cpsc.gov/cpscpub/pubs/5010.html
- www.healthandenergy.com/carbon_monoxide.htm
- www.cmaj.ca/content/166/13/1685.full
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- www.healthvermont.gov/enviro/indoor_air/co.aspx
- www.detectcarbonmonoxide.com/warnings.html